

1                   CLAIMS:

2                   1. A system for providing cyclical impacts, said system  
3                   comprising

4                   a housing with a longitudinal axis,  
5                   an impact member adjacent the housing,  
6                   a movable member movably disposed within the  
7                   housing, the movable member movable within the housing  
8                   transversely to the longitudinal axis of the housing, the  
9                   movable member positioned within the housing with a first  
10                  space on a first side thereof and a second space on a second  
11                  side thereof, gas in the first space and gas in the second  
12                  space, the first space substantially fluidly isolated from the  
13                  second space by the movable member, the movable member movable  
14                  to compress gas in one of the first space and the second space  
15                  while decompressing gas in the other of the first space or  
16                  second space so that a charge of compressed gas exits from the  
17                  housing to move the impact member,

18                  the movable member movable continuously to provide  
19                  a series of a plurality of movements of the impact member, the  
                        system thereby providing a series of a plurality of impacts.

1                   2. The system of claim 1 wherein the system is a system for  
2                   driving a pile into the earth and the housing is positionable  
3                   adjacent the pile so that the impact member impacts the pile.

1                   3. The system of claim 1 wherein the system is a system for  
2                   drilling a borehole into the earth, the system including drill bit  
3                   apparatus, the housing positionable adjacent the drill bit  
4                   apparatus so that the impact member impacts the drill bit  
5                   apparatus.

6                   4. A system for moving a drilling apparatus for drilling a  
7                   borehole in a formation, said system comprising  
8                   a housing with a longitudinal axis,

9                   a movable member movably disposed within the  
10                  housing, the movable member movable within the housing  
11                  transversely to the longitudinal axis of the housing, the  
12                  movable member positioned within the housing with a first  
13                  space on a first side thereof and a second space on a second  
14                  side thereof, the first space substantially fluidly isolated  
15                  from the second space by the movable member, the movable  
16                  member movable to compress gas in one of the first space and  
17                  the second space while decompressing gas in the other of the  
18                  first space or second space so that a charge of compressed gas  
19                  exits from the housing to move an impact member for impacting  
20                  the drill apparatus for drilling the wellbore,

21                   the movable member movable continuously to provide  
22                  a series of a plurality of movements of the impact member.

1                5. A percussion drill assembly for drilling a borehole in a  
2                  formation, said percussion drill assembly comprising

3                   an elongated housing assembly having a first end  
4                  adapted to removably connect said drill assembly to a drill  
5                  string, and a second end adapted to receive a drill bit,

6                   a first compartment formed within said housing  
7                  assembly and having a longitudinal axis,

8                   a hammer piston positioned within said first  
9                  compartment for reciprocal motion within said first  
10                 compartment along the longitudinal axis of said first  
11                 compartment, said hammer piston dividing said first  
12                 compartment into a first chamber and a second chamber which  
13                 are substantially fluidly isolated from each other within said  
14                 first compartment by the presence of said hammer piston,

15                   a fluid compressor positioned within said housing  
16                  assembly and having a first port in said first chamber and a  
17                  second port in said second chamber,

18                   wherein a second compartment is formed within said

19       housing assembly, said second compartment having a  
20      longitudinal axis; wherein said fluid compressor comprises a  
21      compressor piston positioned within said second compartment  
22      for reciprocal motion within said second compartment  
23      transverse to the longitudinal axis of said second  
24      compartment, said compressor piston dividing said second  
25      compartment into a third chamber and a fourth chamber which  
26      are substantially fluidly isolated from each other within said  
27      second compartment by the presence of said compressor piston,  
28                wherein said first port provides fluid communication  
29      with said third chamber, and said second port provides fluid  
30      communication with said fourth chamber,

31                a driver mounted in said housing assembly and  
32      connected to said compressor piston so as to drive said  
33      compressor piston to produce a high fluid pressure in said  
34      first port and a low fluid pressure in said second port during  
35      a first half cycle of operation of said fluid compressor and  
36      to produce a low fluid pressure in said first port and a high  
37      fluid pressure in said second port during a second half cycle  
38      of operation of said fluid compressor, and

39                wherein said driver is connected to said compressor  
40      piston to cause reciprocating movements of said compressor  
41      piston within said second compartment.

1       6. The percussion drill assembly of claim 5 further  
2      comprising

3                seals for sealing said fluid compressor from fluid  
4      communication with any fluid received from the drill string,  
5      whereby said compressor fluid system is a closed fluid system.

1       7. The percussion drill assembly of claim 5 wherein when  
2      said drill assembly is being operated to impart an impact force to  
3      a drill bit, a high fluid pressure in said first chamber and a low  
4      fluid pressure in said second chamber causes a movement of said

5                   hammer piston toward said second chamber, and

6                   wherein when said drill assembly is being operated  
7                   to impart an impact force to a drill bit, a low fluid pressure  
8                   in said first chamber and a high fluid pressure in said second  
9                   chamber causes a movement of said hammer piston toward said  
10                  first chamber.

1                   8. The percussion drill assembly of claim 5 wherein when  
2                   said housing assembly comprises a bit adapter at said second end of  
3                   said housing assembly for receiving a drill bit, said bit adapter  
4                   having an anvil surface exposed to said compartment, and

5                   wherein said drill assembly further comprises a  
6                   drill bit removably connected to said bit adapter, and

7                   whereby a predetermined extent of movement of said  
8                   hammer piston in one of its directions of movement causes said  
9                   hammer piston to strike said anvil surface and impart an  
10                  impact blow to said bit adapter when said drill bit is in  
11                  contact with a borehole bottom.

1                   9. The percussion drill assembly of claim 8 wherein when  
2                   said driver comprises a fluid motor which is driven by a drilling  
3                   fluid passed downwardly through a drill string to the drill  
4                   assembly, and wherein the drilling fluid is exhausted from said  
5                   fluid motor through said second end of said housing assembly and  
6                   through said drill bit.

1                   10. The percussion drill assembly of claim 5 wherein when  
2                   said driver comprises a fluid motor which is driven by a drilling  
3                   fluid passed downwardly through a drill string to the drill  
4                   assembly.

1                   11. The percussion drill assembly of claim 10 wherein when  
2                   said fluid motor has a liquid inlet and a liquid outlet, said fluid  
3                   motor has a stator and a rotor positioned between said liquid inlet  
4                   and said liquid outlet, said driver comprises a rotary shaft and  
5                   said rotor is connected to said rotary shaft so that rotation of

6       said rotor causes corresponding rotation of said rotary shaft,  
7       wherein the rotation of said rotary shaft drives said fluid  
8       compressor, and wherein said liquid inlet of said motor is  
9       connected to an inlet passageway in said first end of said housing  
10      assembly so that liquid from a drill string flows through said  
11      inlet passageway and then flows between said stator and said rotor  
12      to said liquid outlet to effect rotation of said rotor with respect  
13      to said housing assembly, thereby rotating said rotary shaft and  
14      driving said fluid compressor.

1       12. A percussion drill assembly for drilling a borehole in a  
2       formation, the percussion drill assembly comprising

3               an elongated housing assembly having a first end  
4       adapted to removably connect said drill assembly to a drill  
5       string, and a second end adapted to receive a drill bit,

6               a first compartment formed within said housing  
7       assembly and having a longitudinal axis,

8               a hammer piston positioned within said first  
9       compartment for reciprocal motion within said first  
10      compartment along the longitudinal axis of said first  
11      compartment, said hammer piston dividing said first  
12      compartment into a first chamber and a second chamber which  
13      are substantially fluidly isolated from each other within said  
14      first compartment by the presence of said hammer piston,

15               a fluid compressor positioned within said housing  
16       assembly and having a first port in said first chamber and a  
17       second port in said second chamber,

18               wherein a second compartment is formed within said  
19       housing assembly, said second compartment having a  
20       longitudinal axis; wherein said compressor comprises a  
21       compressor piston positioned within said second compartment  
22       for reciprocal motion within said second compartment  
23       transverse to the longitudinal axis of said second

24 compartment, said compressor piston dividing said second  
25 compartment into a third chamber and a fourth chamber which  
26 are substantially fluidly isolated from each other within said  
27 second compartment by the presence of said compressor piston,

28 wherein said first port provides fluid communication  
29 with said third chamber, and said second port provides fluid  
30 communication with said fourth chamber,

31 a driver mounted in said housing assembly and  
32 connected to said compressor piston so as to drive said  
33 compressor piston to produce a high fluid pressure in said  
34 first port and a low fluid pressure in said second port during  
35 a first half cycle of operation of said first compressor and  
36 to produce a low fluid pressure in said first port and a high  
37 fluid pressure in said second port during a second half cycle  
38 of operation of said first compressor,

39 wherein said driver is connected to said compressor  
40 piston to cause reciprocating movements of said compressor  
41 piston within said second compartment,

42 seals for sealing said fluid compressor from fluid  
43 communication with any fluid received from the drill string,  
44 whereby said compressor fluid system is a closed fluid system,

45 wherein said drill assembly is operable to impart an  
46 impact force to a drill bit, a high fluid pressure in said  
47 first chamber and a low fluid pressure in said second chamber  
48 causing a movement of said hammer piston toward said second  
49 chamber,

50 wherein said drill assembly is operable to impart an  
51 impact force to a drill bit, a low fluid pressure in said  
52 first chamber and a high fluid pressure in said second chamber  
53 causes a movement of said hammer piston toward said first  
54 chamber,

55 wherein said housing assembly comprises a bit

56                   adapter at said second end of said housing assembly for  
57                   receiving a drill bit, said bit adapter having an anvil  
58                   surface exposed to said compartment,

59                   wherein said drill assembly further comprises a  
60                   drill bit removably connected to said bit adapter,

61                   whereby a predetermined extent of movement of said  
62                   hammer piston in one of its directions of movement causes said  
63                   hammer piston to strike said anvil surface and impart an  
64                   impact blow to said bit adapter when said drill bit is in  
65                   contact with a borehole bottom,

66                   wherein said driver comprises a fluid motor which is  
67                   driven by a drilling fluid passed downwardly through a drill  
68                   string to the drill assembly, and wherein the drilling fluid  
69                   is exhausted from said fluid motor through said second end of  
70                   said housing assembly and through said drill bit,

71                   wherein said fluid motor has a liquid inlet and a  
72                   liquid outlet, a stator and a rotor positioned between said  
73                   liquid inlet and said liquid outlet, said driver comprises a  
74                   rotary shaft and said rotor is connected to said rotary shaft  
75                   so that rotation of said rotor causes corresponding rotation  
76                   of said rotary shaft, wherein the rotation of said rotary  
77                   shaft drives said fluid compressor, and wherein said liquid  
78                   inlet of said motor is connected to an inlet passageway in  
79                   said first end of said housing assembly so that liquid from  
80                   the drill string flows through said inlet passageway and then  
81                   flows between said stator and said rotor to said liquid outlet  
82                   to effect rotation of said rotor with respect to said housing  
83                   assembly, thereby rotating said rotary shaft and driving said  
84                   fluid compressor.

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1           13. A liquid-driven, gas-operated, percussion drill assembly  
2        for drilling a borehole in a formation, said drill assembly  
3        comprising

4                an elongated housing assembly, said housing assembly  
5        having a first end and a second end opposite said first end,  
6        and a longitudinal axis extending from said first end to said  
7        second end,

8                an end portion of said housing assembly at said  
9        first end being adapted for removably connecting said drill  
10      assembly to a drill string, said end portion having a first  
11      passageway extending therethrough for the passing of a liquid  
12      received from the drill string,

13                an elongated first compartment formed within said  
14      housing assembly, said first compartment having a longitudinal  
15      axis which is at least generally parallel to the longitudinal  
16      axis of said housing assembly,

17                a first piston positioned within said first  
18      compartment for reciprocal motion within said first  
19      compartment transverse to the longitudinal axis of said first  
20      compartment, said first piston dividing said first compartment  
21      into a first right chamber and a first left chamber which are  
22      substantially fluidly isolated from each other within said  
23      first compartment by the presence of said first piston,

24                a first shaft having a longitudinal axis, said first  
25      shaft being rotatably mounted in said housing assembly with  
26      the longitudinal axis of said first shaft being at least  
27      generally parallel to the longitudinal axis of said housing  
28      assembly, said first shaft being engaged with said first  
29      piston such that rotation of said first shaft causes  
30      reciprocating movement of said first piston within said first  
31      compartment,

32                a motor positioned in said housing assembly and

33 having a liquid inlet and a liquid outlet, said motor having  
34 a stator and a rotor positioned between said liquid inlet and  
35 said liquid outlet, said rotor being connected to said first  
36 shaft so that rotation of said rotor causes corresponding  
37 rotation of said first shaft, said liquid inlet of said motor  
38 being connected to the first passageway in said end portion of  
39 said housing assembly so that liquid from said first  
40 passageway flows between said stator and said rotor to said  
41 liquid outlet to effect rotation of said rotor with respect to  
42 said housing assembly, thereby rotating said first shaft and  
43 reciprocating said first piston,

44 an elongated second compartment formed within said  
45 housing assembly, said second compartment having a  
46 longitudinal axis which is at least generally parallel to the  
47 longitudinal axis of said housing assembly,

48 a second piston positioned within said second  
49 compartment for reciprocal motion within said second  
50 compartment along the longitudinal axis of said second  
51 compartment, said second piston dividing said second  
52 compartment into a first upper right chamber and a first lower  
53 chamber which are substantially fluidly isolated from each  
54 other within said second compartment by the presence of said  
55 second piston,

56 a bit adapter having an anvil surface at a first end  
57 thereof and a drill bit receiving opening at a second end  
58 thereof, said bit adapter being removably attached to said  
59 second end of said housing assembly with said anvil surface of  
60 said bit adapter being exposed to said first lower left  
61 chamber,

62 a second passageway providing fluid communication  
63 between said first right chamber and a first one of said first  
64 upper chamber and said first lower chamber,

65                   a third passageway providing fluid communication  
66                   between said first left chamber and a second one of said first  
67                   upper chamber and said first lower chamber,

68                   seals for sealing said first and second compartments  
69                   and said second and third passageways from fluid communication  
70                   with said first passageway, whereby said first and second  
71                   compartments and said second and third passageways constitute  
72                   a closed fluid system,

73                   each of said first right chamber, said first upper  
74                   chamber, said first left chamber, said first lower chamber and  
75                   said second and third passageways having gas therein,

76                   wherein movement of said first piston toward said  
77                   first right chamber compresses the gas in said first right  
78                   chamber and thus increases the pressure of the gas in said  
79                   first right chamber, in said second passageway, and in said  
80                   first one of said first upper chamber and said first lower  
81                   chamber, thereby causing the movement of said second piston  
82                   toward said second one of said first upper chamber and said  
83                   first lower chamber, and

84                   wherein movement of said first piston toward said  
85                   first left chamber compresses the gas in said first left  
86                   chamber and thus increases the pressure of the gas in said  
87                   first left chamber, in said third passageway, and in said  
88                   second one of said first upper chamber and said first lower  
89                   chamber, thereby causing the movement of said second piston  
90                   toward said first upper chamber and said first lower chamber.

1                   14. The liquid-driven, gas-operated, percussion drill  
2                   assembly of claim 13 further comprising

3                   a drill bit removably connected to said bit adapter.

1                   15. The liquid-driven, gas-operated, percussion drill  
2                   assembly of claim 13 further comprising

an eccentric element on said first shaft for acting on said first piston such that rotation of said first shaft in a single direction causes reciprocating movements of said first piston within said first compartment perpendicular to the longitudinal axis of said first compartment.

16. The liquid-driven, gas-operated, percussion drill assembly of claim 13 wherein said motor has a bypass passageway therein in communication with said first passageway for passing a portion of the liquid received from said drill string to said liquid outlet of said motor without said portion of the liquid going between said stator and said rotor.

17. The liquid-driven, gas-operated, percussion drill assembly of claim 13 wherein said rotor has a central longitudinal axis, said bypass passageway extends internally through said rotor, and said bypass passageway is not centrally located in said rotor.

18. The liquid-driven gas-operated, percussion drill assembly of claim 13 wherein said second end of said housing assembly comprises an annular chuck positioned outwardly of and coaxially with an intermediate portion of said bit adapter, whereby said bit adapter can slide axially with respect to said chuck so that said bit adapter can move downwardly with respect to said chuck when the drill bit is not in contact with a borehole bottom.

19. A method of operating a percussion drill assembly for drilling a borehole in a formation, said method comprising

charging a closed fluid system of a percussion drill assembly with a fluid under pressure, said percussion drill assembly comprising an elongated housing assembly having a first end adapted to removably connect said drill assembly to a drill string, and a second end adapted to receive a drill bit, a first compartment formed within said housing assembly and having a longitudinal axis, a hammer piston positioned within said first compartment for reciprocal motion within

11       said first compartment along the longitudinal axis of said  
12       first compartment, said hammer piston dividing said first  
13       compartment into a first chamber and a second chamber which  
14       are substantially fluidly isolated from each other within said  
15       first compartment by the presence of said hammer piston, a  
16       fluid compressor positioned within said housing assembly and  
17       having a first port in said first chamber and a second port in  
18       said second chamber, wherein a second compartment is formed  
19       within said housing assembly, said second compartment having  
20       a longitudinal axis; wherein said compressor comprises a  
21       compressor piston positioned within said second compartment  
22       for reciprocal motion within said second compartment  
23       perpendicular to the longitudinal axis of said second  
24       compartment, said compressor piston dividing said second  
25       compartment into a third chamber and a fourth chamber which  
26       are substantially fluidly isolated from each other within said  
27       second compartment by the presence of said compressor piston,  
28       wherein said first port provides fluid communication with said  
29       third chamber, and said second port provides fluid  
30       communication with said fourth chamber, a driver mounted in  
31       said housing assembly and connected to said compressor piston  
32       so as to drive said compressor piston to produce a high fluid  
33       pressure in said first port and a low fluid pressure in said  
34       second port during a first half cycle of operation of said  
35       first compressor and to produce a low fluid pressure in said  
36       first port and a high fluid pressure in said second port  
37       during a second half cycle of operation of said first  
38       compressor, and wherein said driver is connected to said  
39       compressor piston to cause reciprocating movements of said  
40       compressor piston within said second compartment,  
41               connecting said first end of said drill assembly to  
42       a drill string,

connecting said second end of said drill assembly to a drill bit,

operating said drill assembly to impart an impact force to said drill bit by actuating said motor to rotate said shaft and thereby reciprocate said compressor piston, thereby causing the movement of said hammer piston whereby movement of said hammer piston imparts an impact force to said drill bit.

20. The method of claim 19 further comprising

rotating the drill string to thereby rotate said drill bit.

21. The method of claim 19 further comprising

passing drilling fluid through the drill string into and through said motor to actuate said motor and passing drilling fluid from to and through said drill bit to flush drilling debris from the drill bit.

22. The method of claim 19 wherein the fluid which is charged to said closed fluid system is a gas.

23. A method for providing cyclical impacts, the method comprising

impacting an item with an impact member of a system, the system for providing cyclical impacts, the system comprising a housing with a longitudinal axis, the impact member adjacent the housing, a movable member movably disposed within the housing, the movable member movable within the housing transversely to the longitudinal axis of the housing, the movable member positioned within the housing with a first space on a first side thereof and a second space on a second side thereof, gas in the first space and gas in the second space, the first space substantially fluidly isolated from the second space by the movable member, the movable member movable to compress gas in one of the first space and the second space while decompressing gas in the other of the first space or

16 second space so that a charge of compressed gas exits from the  
17 housing to move the impact member, the movable member movable  
18 continuously to provide a series of a plurality of movements  
19 of the impact member, the system thereby providing a cyclical  
20 series of a plurality of impacts.

1 24. A method of drilling a wellbore in an earth formation  
2 with a drilling apparatus, the method comprising

3 impacting a drilling apparatus with an impact member  
4 of a system, the system for moving the impact member, the  
5 system comprising a housing with a longitudinal axis, a  
6 movable member movably disposed within the housing, the  
7 movable member movable within the housing transversely to the  
8 longitudinal axis of the housing, the movable member  
9 positioned within the housing with a first space on a first  
10 side thereof and a second space on a second side thereof, the  
11 first space substantially fluidly isolated from the second  
12 space by the movable member, the movable member movable to  
13 compress gas in one of the first space and the second space  
14 while decompressing gas in the other of the first space or  
15 second space so that a charge of compressed gas which exits  
16 from the housing to move an impact member for impacting the  
17 drill apparatus for drilling the wellbore, the movable member  
18 movable continuously to provide a series of a plurality of  
19 movements of the impact member to provide a plurality of  
20 impacts to the drilling apparatus.